Stable Isotope Labeling as a Tool to Advance the Development of Sustainable Bioenergy Systems

A major challenge in bioenergy research is to improve the environmental sustainability of bioenergy agroecosystems. By using stable isotope methods to quantify pools and fluxes of carbon (C), water, and nutrients, there is tremendous potential to advance the mechanistic understanding of bioenergy systems' functioning from the subcellular to the ecosystem scale. In particular, isotope labeling of whole plants with ^{13}C-labeled carbon dioxide (CO_2) and ^{15}N-labeled fertilizer is a powerful approach to investigate plant-soil-microbe interactions. Further, knowledge gained from these applications can contribute to basic understanding of the critical zone, and potentially inform process-based models to enable *in silico* assessment of biogeochemical responses under various climate and land management scenarios. Here we present a newly built stable isotope labeling facility for labeling plants with ^{13}C-CO_2 and tracing isotope-labeled C and nitrogen (N) through the plant, soil, and atmosphere in high-yielding bioenergy grasses. We also outline a planned experiment to investigate the effects of sorghum (*Sorghum bicolor*), a lipid-enhanced bioenergy crop engineered by the Center for Advanced Bioenergy and Bioproducts Innovation, on soil microbial communities and C cycling. This facility will enable targeted investigation to enhance the efficiency and sustainability of bioenergy crops, and to drive further insights into the mechanistic underpinnings of plant metabolism and plant-microbe-mineral interactions. Initially, the system is designed to be used with sorghum and features 32 gas-tight, humidity-controlled, adjustable-volume chambers that each house a single plant, with 50-100 cm of soil depth and roughly 1.5 m of growing height. Our planned labeling experiment will trace ^{13}C-CO_2 into the particulate and mineral-associated C pools throughout the soil profile, and use stable isotope probing of the microbial community, to elucidate the role of rhizodeposition and soil microbial activity in shunting newly fixed atmospheric C into fast-cycling vs. persistent soil C pools. Together, our facility and the proposed stable isotope labeling experiment exemplify the potential for methodological advances and improved management practices in the field of sustainable bioenergy.

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